

## Evaluation on Regional Ecological Benefits of Windbreak Systems

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**Abstract** This paper studied how dynamically to evaluate regional ecological benefits of windbreak systems in a county scale. Data of air temperature, humidity, wind speed, crop yield and forest cover percentage were investigated and collected in some of counties of Heilongjiang Province, where windbreak systems were established in the last thirty years. Through analysis, an evaluation index system estimating regional ecological benefits of windbreak systems was set up, which consists of both a vegetation index system and a climate index system. The former includes a forest cover percentage index and a crop yield index; the later does three variable indexes of wind speed, air temperature and humidity. An integrated regional ecological benefit index was developed through combinations of some coined evaluation indexes from the evaluation system. And to take Zhaozhou County and Anda County as a case study, the regional ecological benefits since establishment of windbreak systems of the two counties were evaluated dynamically using the integrated index.

**Key words:** Windbreak system, Regional ecological benefit, Index, Evaluation

### Introduction

In "Three North" areas of China( Northwest, Northeast and North Central China), the construction of windbreak systems has played an active role in improving the quality of natural environment, accelerating the development of agriculture, forestry and animal husbandry, and increasing ecological, social and economical benefits. The benefits, therefore, attracted public attention and have been studied widely and deeply. Most of researches are on dynamic, thermodynamic, hydrological and biological effects of windbreaks and soil improvements. And most of research methods are non-dynamically to evaluate the benefit which exists only at present, in a small area with one or several shelterbelts, or with one or several windbreak nets. But there are few researches on regional benefits in large areas (generally, a whole county) with windbreak systems, especially on how dynamically to evaluate the regional ecological benefits, how to choose evaluation indexes and an index system, and how to compare the benefits from different periods and regions.

### Research Approach

Evaluations of windbreak benefits are usually studied by observing and comparing the differences of factors and indexes between areas sheltered by windbreaks and non-windbreak areas, which only shows effects of windbreaks on individual factors and can not show integrated benefits from the windbreaks. For example,

most evaluations have only estimated how much wind speed is decreased, how much humidity is increased and how much crop yield is raised, but have not indicated how much integrated ecological benefits of the windbreaks at all. Therefore, the evaluation can not compare the benefits of different periods and regions. For instance, in a certain year, we measured that wind speed decreased by 10% , and next year decreased by 20%, but we can not simply say that the benefit of windbreaks increased. The reason is that wind is just one of the many factors, and in different years wind speed changes lot so the effect of windbreaks on wind speed is different(usually, the higher wind speed is, the greater effect of windbreaks on wind protection ).

The regional ecological benefit defined in this paper is meant the whole ecological benefits brought by the windbreak systems within a county. The past method is not suitable for the object of this study to evaluate the regional ecological benefit, because there are three reasons: 1) a whole county is used as an evaluated area, so there will be no check areas within the county; 2) it is not necessary to do this research if some individual factors are only evaluated as usual, because those factors, such as average wind speed, air temperature, humidity, crop yield can be got directly from Weather Forecast Bureau or Statistic Bureau. 3) a regional ecological benefit consists of many benefits of factors such as vegetation, animal, meteorology, hydrology, soil and so on, whereas, there should be an integrated quantitative index to present these benefits (but every factor benefit has a different weight to estimate the whole benefits.)

This study tries to solve these problems above and

systematically, completely and precisely to evaluate the whole regional ecological benefits of windbreak systems in counties of "Three North" areas. And the used research method should be able to compare ecological benefits of windbreak systems being in different periods and regions. The chosen evaluation index should be helpful to be an objective basis in improving the ecological environment, to discern and judge the whole level and week points of windbreak systems, and instruct the construction of windbreak engineering in "Three North" areas.

## Research Method

### Evaluation indexes choosing

Choosing what indexes is key to evaluate regional ecological benefits of windbreak systems. Indexes chosen should not be unsuitable, too many and too few. If unsuitable, they can not represent ecological benefits; if too few, they cannot show completely the whole ecological benefit; if too many, they are difficult to use and tend to exaggerate the effects of windbreaks. The choosing of indexes, therefore, should follow such rules:

(1) indexes should be representative correctly, completely and systematically in representing the attribute of ecological benefits but should not be too many.

(2) indexes should have the clear definitions with both connotation and extension of meanings. The internal relationship among them should also be noticed to avoid overlapping indexes.

(3) an integrated index without unit should be derived from all indexes, and its value not be an absolute value but a relative one, which can show the degree of the regional ecological benefits.

(4) indexes should be easier to measure, investigate and collect, and the index calculating method should be simple and easy to apply.

According to the rules, the indexes should not be one or one kind, but many and many kinds. Ecology is the science regarding organism and its environment, so the ecological benefits should be made up both biological benefits and environmental ones. And both are described by respective indexes(see Fig.1).

In the biological benefits, vegetation indexes are more stable and reliable, and easier to measure than animal indexes. It is better to chose forest cover percentage and crop yield indexes than to chose animal ones in evaluation of biological benefits. In the environmental benefits, meteorological indexes are most closely related to windbreaks than hydrological and soil indexes, and are most evidently influenced by windbreaks in a large area such as a county. Therefore, air

temperature, humidity and wind speed are most representative indexes to evaluate environmental benefits. So we chose two kinds of indexes including five factors to evaluate the regional ecological benefits from windbreak systems, that is, forest cover percentage and crop yield for the vegetation index, and wind speed, air temperature and humidity for the meteorological index.

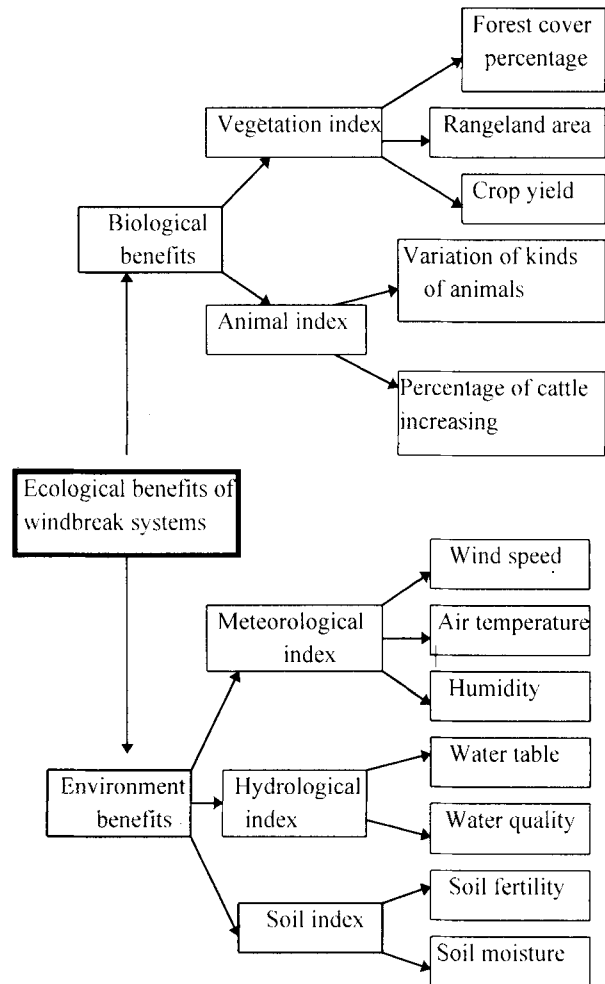


Fig. 1. Ecological benefit indexes of windbreak systems

### Data collecting and processing

According to the chosen indexes, approximately, three hundred thousand data of forest cover percentage, crop yield and meteorological factors, from 1968 to 1993, were collected from 12 County forest bureaus (Zhaozhou, Anda, Tailai, Zhaodong, Hailun, and so on), Heilongjiang Statistic Bureau, Meteorological Bureau, and Forest Department. Moreover, data of the same meteorological factors from Shangzhi County(no windbreaks) were also collected for used check values. Later, these data are input into Foxbase data base, and are calculated for the need of indexes.

### Evaluation index and index system

#### Index construction

Evaluation index values

change with period, region and status of windbreaks, therefore, the absolute values are not appropriate to be used directly. We coined relative evaluating indexes without unit to represent ecological benefit.

Forest cover percentage index  $X_{11}$

$$X_{11} = \frac{F - F_0}{F_0}$$

where:  $F$  is measured forest cover percentage;  $F_0$  is planning forest cover percentage(22%).

Crop yield index  $X_{12}$

$$X_{12} = \frac{C - C_0}{C_0}$$

where:  $C$  is measured crop yield, kg/hm<sup>2</sup>;  $C_0$  is planning crop yield, 11250 kg/hm<sup>2</sup>.

Integrated index of biological benefits  $X_1$  is

$$X_1 = X_{11}P_{11} + X_{12}P_{12}$$

where:  $P_{11}$  and  $P_{12}$  are the weights of the forest cover percentage index and the crop yield index in the integrated index of biological benefits, respectively.

Wind speed index  $X_{21}$  is

$$X_{21} = \frac{W_0 - W}{W_0}$$

where:  $W_0$  is measured mean wind speed in none windbreak county(Shangzhi County);  $W$  is measured mean wind speed in windbreak counties.

Air temperature index  $X_{22}$  is

$$X_{22} = \frac{T_0 - T}{T_0}$$

where:  $T_0$  is measured mean temperature in none windbreak county(Shangzhi County);  $T$  is measured mean temperature in windbreak counties.

Humidity index  $X_{23}$  is

$$X_{23} = \frac{S - S_0}{S_0}$$

where:  $S$  is measured mean humidity in none windbreak county (Shangzhi County);  $S_0$  is measured mean humidity in windbreak counties.

Integrated index of environment benefits  $X_2$  is

$$X_2 = X_{21}P_{21} + X_{22}P_{22} + X_{23}P_{23}$$

where:  $P_{21}$ ,  $P_{22}$  and  $P_{23}$  are the weights of the wind speed, the air temperature and the humidity indexes in the integrated index of environment benefits, respectively.

Integrated index of ecological benefits  $X$  is

$$X = X_1P_1 + X_2P_2$$

where:  $P_1$  and  $P_2$  are the weights of the integrated index

of biological benefits and the integrated index of environment benefits in the integrated index of ecological benefits.

**Index system** An evaluation index system of regional ecological benefits of windbreaks is set up according to the evaluation indexes and the coined indexes (see Fig.2).

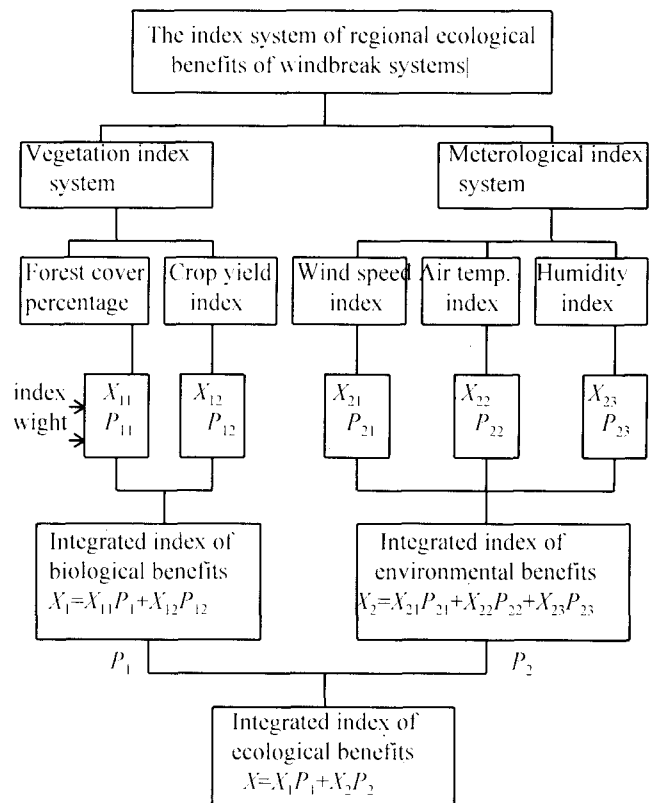


Fig. 2. Framework of the index system of regional ecological benefits of windbreak systems

The integrated index of ecological benefits is an integration of all the evaluation indexes but not a simple sum of all the indexes. It represents the contribution of each index unevenly according to the correlation of each index to the whole ecological benefit. Its value ranges  $0 \geq X \geq -1$ . The nearer upon 0 the value is, the better the ecological benefit, the nearer upon -1, the poorer the ecological benefit.

#### Calculation of index weight

All the indexes of biological and environmental benefits have their own weights to indicate the importance of these indexes to the whole regional ecological benefit.

There are many methods to determine the weight of an index. The most simple method is to give indexes weights directly based on your experience. This paper uses a combination of the correlation coefficient and

experience methods to determine the weights of the evaluation indexes.

### Calculation of vegetation and meteorological benefit weights

Because the ecological benefit of windbreaks has two main parts: biological and environmental benefits which are separate, associated and complementary each other and equally important, both the biological benefit weight  $P_1$  and the environmental benefit weight  $P_2$  should be 0.5.

**Weight of vegetation indexes** The forest cover percentage and crop yield are used as independent variables, and wind speed, temperature and humidity as dependent variables to develop a multi variate regression equation by which multiple correlation coefficients  $R_1$  and  $R_2$  are calculated. Thus,  $P_{11}$  and  $P_{12}$  are calculated by the formula below.

$$P_{11}=R_1/R_1+R_2; \quad P_{12}=R_2/R_1+R_2.$$

**Weight of meteorological indexes** Using the calculated partial correlation coefficients ( $r_1$ ,  $r_2$  and  $r_3$ ) of wind speed, air temperature, and humidity, the weight of  $P_{21}$ ,  $P_{22}$  and  $P_{23}$  can be calculated by the formula below.

$$P_{21}=r_1/r_1+r_2+r_3; \quad P_{22}=r_2/r_1+r_2+r_3; \quad P_{23}=r_3/r_1+r_2+r_3.$$

Calculated with the formulas above, the weight of every index is, respectively.

Weight of vegetation indexes,  $P_1=0.5$

weight of forest cover percentage index,  $P_{11}=0.5$ ;

weight of crop yield index,  $P_{12}=0.5$ .

Weight of meteorological index,  $P_2=0.5$

weight of wind speed index,  $P_{21}=0.4$ ;

weight of temperature index,  $P_{22}=0.3$ ;

weight of humidity index,  $P_{23}=0.3$ .

### Practical Evaluation of Regional Ecological Benefits

Taken Zhaozhou County and Anda County as an example, regional ecological benefits since establishment of windbreak systems of the two counties are evaluated using the integrated index of ecological benefit by different constructing stage windbreaks. There are three stages of construction of windbreaks: 1968-1977, 1978-1987 and 1988-1992. The integrated index of ecological benefits are calculated at different stage of windbreak construction (see Fig. 3). The ecological benefits of these two counties are both increasing. In Anda, the value increased from -0.54 to -0.37 and to -0.34. While in Zhaozhou, from -0.57 to -0.39 and to -0.31. This means that the regional ecological benefits of the first two stages in Anda was greater than those of Zhaozhou, but, in the last stage, is greater in Zhaozhou than in

Anda. So the ecological benefits of Zhaozhou increased more rapidly than those of Anda.

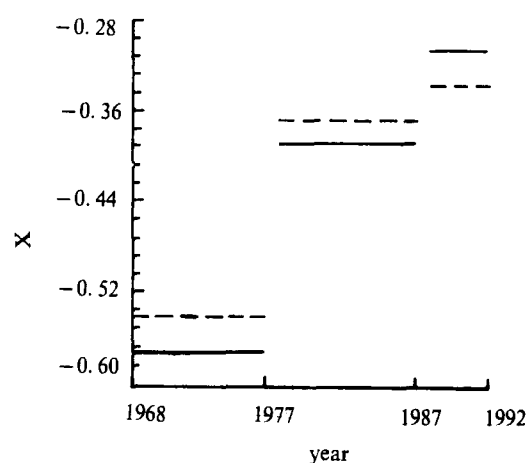


Fig. 3. The dynamic changes of ecological benefits of Anda and Zhaozhou counties

### Conclusion and Discussion

Choosing of indexes is the most important for the evaluation of regional ecological benefits. Our choice of forest cover percentage, crop yield, wind speed, air temperature and humidity are very suitable but not so complete. If we added rangeland and cattle indexes, the evaluation would be better.

The evaluation index system and the integrated evaluated index proposed by us enable the quantitative evaluation of regional ecological benefits, and can compare it by different times and regions, and make it easier to evaluate the benefits dynamically. In the research of evaluation of windbreak benefits, this paper is the first to construct the integrated evaluation index converting many indexes into one index value, which can classify windbreak constructions based on the grade of the value. This is helpful to instruct the constructions of windbreak systems in "Three North" areas.

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